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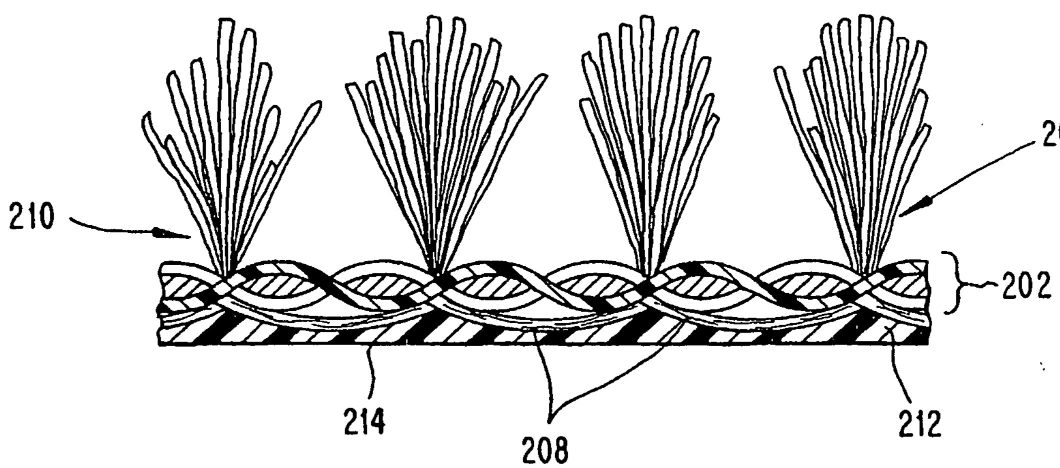

(57) Abstract

The disclosure relates to a carpet product, a process for manufacturing carpet, and an apparatus used in a carpet manufacturing process. The carpet product is made from tufted polymer filament yarn wherein the individual yarn filaments of the yarn back loops are integrally fused so that the carpet resists fuzzing. The primary backing preferably is modified polypropylene in the fill direction. Further, the primary backing may be coated with a polymer before tufting to adhere or integrally fuse the inside of the fiber tuft to the primary backing. An optional secondary backing is preferably made of tape yarn in both directions. The process includes providing a carpet base having a primary backing penetrated by yarn, applying heat to the underside of the primary backing, extruding a heated sheet of polymer and continuously contacting the heated extruded sheet of polymer with the base. The apparatus includes a source of carpet precursor, a heated cylinder for heating the underside of the carpet, and extruder and a casting roll against which the extruded sheet and heated carpet are pressed.

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CARPET AND CARPET MAKING METHODS

FIELD OF THE DISCLOSURE

The application relates to pile carpet and, in particular, to a carpet in which the face yarn is secured to one or more backing layers. Apparatus and methods for manufacturing such carpet are also disclosed.

BACKGROUND

Most carpets are composite structures in which the face fiber forming the pile, i.e., the surface of the carpet, penetrates at least one backing layer. The base portions of the facing yarn extend through the backing and are exposed on the bottom surface of the primary backing. Such carpets, generally termed tufted carpets, may be cut pile or loop pile. Aspects of the present invention are also applicable to most other types of carpet, including woven or knitted carpets such as Berber carpets and certain sports surfaces, such as artificial turf or grass.

The basic manufacturing approach to the commercial production of tufted carpeting is to start with a woven scrim or primary carpet backing and to feed this into a tufting

machine or a loom. The carpet face fiber is needled through and embedded in the primary carpet backing, thus forming a carpet precursor or base, sometimes called greige goods. Upstanding loops on the upper side of the carpet may be cut to produce cut pile carpet. Yarn loops or knots are usually exposed on the underside of the greige goods.

Greige goods are typically backed with an adhesive coating in order to secure the face yarn to the primary backing. Low cost carpet often receives only a latex adhesive coating as the backing. This type of carpet is widely used in boats and is called marine backed carpet. Typically, the marine backed carpets are backed with a latex adhesive coating that is water and/or mildew resistant. Higher cost carpet often receives both a latex adhesive coating and a secondary backing.

The face fiber or yarn used in forming the pile of a tufted carpet is typically made of any one of a number of types of fiber, e.g., nylon, acrylic, polypropylene, polyethylene, polyester, rayon, wool, cotton and the like. Face yarns used in carpet include spun staple yarn and bulk continuous filament (BCF) yarn which is made up of tens or hundreds of individual fibers, generally about 50-200 individual fibers, though more or less fibers can be used.

Fibrillated polypropylene grass yarn is also often used as a face yarn.

The individual yarn, once made, is often twisted by itself or in combination with two or more yarns to increase the total denier. For example, two yarns of 1500 denier each can be twisted together to produce a 3000 denier yarn, or three yarns of 1000 denier each can be twisted together to produce a 3000 denier yarn made up of BCF or spun staple feeder yarn. The two or more yarns can be the same color or different colors. Thus, a much wider range of yarn deniers and colorations is made possible. The yarns often are textured or air entangled to achieve a different appearance. The twisting, texturing and air entangling may require that the yarn receive a spin finish that makes the yarn surface easier to work with in the fiber processing. However, the spin finish complicates adhesion of other materials in later processing, for example, in coating the yarns.

Primary backings for tufted pile carpets are typically woven or non-woven fabrics made of one or more natural or synthetic fibers or yarns, such as jute, wool, polypropylene, polyethylene, polyester, nylon, rayon and the like. Films of synthetic materials, such as polypropylene, polyethylene and ethylene-propylene copolymers, may also be used to form the

tape for weaving the primary backing. When tape yarns are used, they are woven into a backing fabric which may consist of the same or different materials in the warp and fill directions. The carpet face fiber is usually embedded in the primary backing such that it wraps around the fill material.

The application of the latex adhesive to the primary backing involves coating the bottom surface of the formed greige goods with a latex polymer binder such as a styrene-butadiene copolymer. The viscosity of the latex adhesive is similar to water and the latex adhesive flows relatively easily into the back of the carpet, wetting out the fiber bundles and penetrating the primary backing. The coated greige goods are passed through an oven to dry the latex adhesive coating. In this manner, the face fibers are attached to the primary backing by the latex binder.

It is known in the art to prepare the greige goods for coating by subjecting the back of the greige goods to a gas flame to reduce the bulk of the protruding face yarn, particularly in greige goods with large knots, in order to reduce the amount of latex adhesive necessary to provide a smooth, well-covered surface. It is also known to apply pressure and low level heat (i.e. below yarn melting

temperature) to flatten the knots prior to the application of the latex adhesive.

If desired, a secondary backing may be bonded to the undersurface of the primary backing. To produce tufted carpets with a secondary backing, the bottom surface of the greige goods is coated with a latex polymer binder. The secondary backing is applied to the coated bottom surface and the resulting structure is passed through an oven to dry the latex adhesive coating to bond the secondary backing to the greige goods.

Secondary backings for tufted pile carpets are typically woven or non-woven fabrics made of one or more natural or synthetic fibers or yarns. In particular, secondary backings for tufted pile carpets are open weave or leno weave, having tape yarn in the warp direction, usually of polypropylene, and spun staple fiber in the fill direction. The spun staple fiber is very costly, but is used to increase adhesion between the backing and latex adhesive coating normally used. The spun stable fiber is hairy when formed and, after the yarn is woven, it is actually run against an abrasive roll to make the spun yarn more hairy. The latex is then able to wet out all the little hairs, improving adhesion of the secondary backing to the carpet. However, spun staple yarn is not as

strong as tape yarn. Therefore, a strong and less expensive secondary backing material is desirable.

The above-described methods have disadvantages in that they require a drying step and thus an oven to dry the latex polymer binder. The drying step increases the cost of the carpet and limits production speed. Furthermore, it has been reported that latex adhesive compositions generate gasses that may be the cause of headaches, watery eyes, breathing difficulties and nausea, especially when used in tightly sealed buildings. *See* Herligy, The Carpet & Rug Industry, October 1990. An additional problem sometimes encountered with the latex coating is that the latex may go all the way through the primary backing and ruin the appearance of the carpet due to excessive penetration caused by the low viscosity of the latex. In addition, overheating of the carpet may occur during drying of the latex, which in turn may affect the shade of the carpet.

Consequently, carpet manufacturers have been attempting to develop a new approach for the preparation of tufted carpets. One such method is the preparation of tufted carpets with a hot-melt adhesive composition instead of a latex composition.

Hot-melt adhesives are amorphous polymers that soften and flow sufficiently to wet and penetrate the backing surfaces and tuft stitches of carpets upon application of sufficient heat. Furthermore, hot-melt adhesives tend to adhere to the backing surfaces and/or tuft stitches.

The hot-melt compositions are selected for their adhesive properties in adhering to the tufts of face yarn, to the primary backing and to the secondary backing, as well as adhering the various layers of the carpet product to each other. Such compositions are generally amorphous or substantially non-crystalline due to the adhesive properties of such polymers.

By the use of hot-melt adhesive, the necessity of drying the composition after application is eliminated and, further, when a secondary backing material is desired, it can be applied directly after, or in conjunction with, the hot-melt composition application without requiring an intervening drying step.

Application of a hot-melt composition is generally accomplished by passing the bottom surface of the greige goods over an applicator roll positioned in a reservoir containing the hot-melt composition in a molten state. A doctor blade is ordinarily employed to control the amount of

adhesive which is transferred from the application roll to the bottom surface of the structure. Alternatively, the hot melt adhesive is extruded from a die and falls onto the greige goods, thereby coating the greige goods. After application of the hot-melt composition to the bottom surface of the greige goods, and prior to cooling, the secondary backing, if desired, is brought into contact with the bottom surface, and the resulting structure is then passed through nip rolls and heated.

The activation temperature of a hot-melt adhesive, i.e., the temperature at which the adhesive softens and flows sufficiently to wet and penetrate the backing surfaces and tuft stitches, is below the temperature at which the backing and face yarns melt or otherwise distort. Otherwise, the backing and face yarns may suffer other damage due to heating.

The compositions which work best as adhesives are those that can adhere to nylon or other materials from which the fibers are made. For example, as discussed in GB 971,958, the adhesive composition may include modified olefins such as olefin copolymers of ethylene, butylene or propylene with polar monomers such as, but not limited to, methyl methacrylate, vinyl acetate, ethyl acrylate and methyl

acrylate. The resulting carpet looks good and has many potential benefits over the latex-coated carpet.

However, it has been found that the tensile strength of hot-melt adhesives is very low, on the order of one-tenth the tensile strength of polypropylene, and about one-seventh the strength of ethylene copolymers. Therefore, hot-melt adhesive carpets generally are deficient in tuft pull strength (force required to remove a tuft from the carpet), particularly as measured by the fiberblock test or "Velcro Test," wherein a two pound Velcro® roller approximately three and one-half inches wide and one and one-half inches in diameter of well-known hook and loop fastening material is rolled repeatedly over the loop pile of the carpet, for example, ten times. The carpet is then inspected for protruding fibers or fuzz (short individual filaments removed from the fiber bundles).

A further problem with hot-melt adhesive is that it begins to loose temperature and increase in viscosity as soon as it leaves the die or is extracted from the reservoir. The hot-melt adhesive loses some heat to the surrounding air in the short distance from die or reservoir to carpet. The carpet further acts as a heat sink for the heat of the hot-melt adhesive, causing the viscosity to drop off sharply.

Nip pressure can be applied to help the hot-melt adhesive to penetrate the greige goods, but this forces the melt against and into the relatively cold carpet, even further lowering the melt temperature and viscosity.

This is even further complicated by the fact that the carpet can be made from yarns that have been twisted together, for example, two or more feeder yarns twisted into one larger yarn. The tufting process may also stitch several yarns over each other, in effect burying yarns under overlapping stitches, thus preventing the adhesive from reaching all of the fibers. Any finish or coating such as a spin finish that may have been originally applied to the yarn also complicates this by making adhesion of the melt difficult. The result is that total penetration and wetting of the yarn back loops is usually not achieved and, thus, the tuft pull strength is very low.

Thus, conventional carpet and carpet manufacturing processes have inherent problems. Specifically, the adhesives used to adhere the tufts of face fiber to the primary backing and to adhere the secondary backing to the primary backing include compositions which require lengthy drying times, thus slowing down the manufacturing process. Further, these adhesives may excessively penetrate the

fibers, distorting the appearance of the carpet face. In addition, use of latex compositions as adhesives may produce noxious gases which create health hazards. Many of the hot-melt adhesive compositions conventionally employed in the manufacture of carpet do not result in reproducible consistency regarding scrim bonds (force required to remove the secondary backing from the finished carpet), tuft pull strength and fuzz resistance (an indication of the amount the individual carpet yarns may fuzz and form pills).

In the original parent application Serial No. 07/883,093, now U.S. Patent No. 5,240,530, there are disclosed certain methods for producing carpet. According to the teachings of that application, a thermoplastic polymer sheet may be extruded into contact with greige goods to integrally fuse the primary backing, face yarn and extruded sheet. Cut pile carpet is presented as exemplifying the use of the methods. No latex or adhesive application is required, nor is a backing step required, though one may be employed in some products.

It is known that latex adhesives, if properly applied, can provide sufficient binding of carpet fibers to permit manufacture of loop pile carpets which can pass the Velcro® test. It is important that any proposal to replace the use

of conventional adhesives be likewise capable of producing a carpet in which the face yarn or fibers are securely attached to the carpet, and, in particular, capable of producing loop pile carpet made with bulk continuous filament (BCF) face yarn or spun staple yarn which can pass the Velcro® test.

The present application includes disclosure of improved carpets and improved techniques for manufacturing carpets which retain various advantages of the carpets and methods initially disclosed in the original parent application.

SUMMARY OF THE DISCLOSURE AND OBJECTS OF THE INVENTION

The present disclosure relates to a novel carpet product and method and apparatus for producing such a carpet. The present disclosure further relates to an improved carpet and method for producing a carpet that overcomes many of the problems associated with a conventional carpet and carpet manufacturing processes.

The present disclosure particularly relates to a carpet having at least a primary backing, a yarn made up of a plurality of thermoplastic fibers wherein the yarn is tufted in the primary backing with back loops of fiber on the underside of the primary backing wherein a portion of

substantially all of the plurality of fibers is integrally fused together, and a greige goods coating of a thermoplastic polyolefin polymer having recurring polar moieties which contacts one or more of the integrally fused fibers and primary backing.

The present disclosure further relates to a process for manufacturing a carpet including tufting a primary backing with a yarn to form a carpet base having portions of the yarn protruding from the upper side of the primary backing and back loop portions of the yarn exposed on the underside of the primary backing, heating the underside of the carpet base to heat the back loop portions of the yarn to integrally fuse individual fibers of the yarn together, and applying a greige goods coating of thermoplastic polyolefin polymer having recurring polar moieties directly to the underside of the carpet base to adhere or integrally fuse a portion of substantially all the fibers in the back loops.

A further object of the invention is a carpet having a primary backing coated on one side with a primary backing coating of thermoplastic polyolefin polymer having recurring polar moieties wherein a face yarn made of a plurality of fibers in a fiber bundle is tufted through the coated primary backing, having back loops on the underside of the coated

primary backing, which adhere or integrally fuse thereto, and a greige goods coating comprising a second thermoplastic polyolefin polymer having recurring polar moieties contacting one or more of the fiber back loops and coated primary backing.

Another object of the invention is a method for manufacturing a carpet including coating a primary backing with a primary backing coating of thermoplastic polyolefin polymer having recurring polar moieties, fixing tufts of carpet fibers to the coated primary backing so that the tufts protrude from the top surface of the coated primary backing to form a tufted base and back loop portions of the carpet fibers are exposed on the underside of the primary backing, contacting the lower surface of the tufted base with a greige goods coating of thermoplastic polyolefin polymer having recurring polar moieties, and adhering or integrally fusing at least one of the coated primary backing or fiber back loops to the greige goods coating.

It is a further object of the invention that the primary backing adhere or integrally fuse to the yarn fibers. Preferably, the primary backing comprises at least in either the warp or fill direction a thermoplastic polyolefin polymer having recurring polar moieties, allowing the fibers of the

face yarn to better adhere to the primary backing around which they are wrapped, thereby preventing pull-out of the fibers. Advantageously, the thermoplastic polyolefin polymer having recurring polar moieties is in the fill direction. Further, it is preferable that the thermoplastic polyolefin polymer having recurring polar moieties for use in the primary backing is a propylene copolymer or polypropylene graft polymer. Various specific compositions are employed in preferred embodiment of the present invention.

The present disclosure further provides a secondary backing which comprises polypropylene tape yarn in both the warp and fill directions, thus reducing cost and improving strength.

It is another object of the present invention to provide a process for manufacturing a carpet made from thermoplastic polymers which satisfies commercial requirements relating to resistance to fuzzing, yarn integrity, tuft binding and lamination strength.

It is another object of this invention to reduce the cost of manufacturing carpets.

It is a further object of this invention to improve the adhesion between layers binding the carpet, thereby improving

carpet strength, yarn integrity, tuft binding, laminative strength and resistance to fuzzing.

The present disclosure also relates to carpet making machinery. In one embodiment, a carpet precursor is supplied to an arrangement of rollers including a fluid heated roller which is pressed against the underside of the carpet precursor. In a preferred embodiment, an extruder directly extrudes a hot thermoplastic sheet onto the heated underside of the carpet precursor. The laminate so formed is pressed against a cooled casting roll.

In an alternate embodiment of the present invention, a preformed sheet of thermoplastic polymer is simultaneously heated and laminated with a carpet precursor in an apparatus including a continuous moving surface or belt. The belt is differentially heated so that it is relatively hot at the location where it first contacts the polymer sheet. The belt is moved and cooled so that it readily separates from the underside of the carpet after the carpet precursor and polymer sheet have been adhered or integrally fused.

Accordingly, it is an object of the present invention to provide machinery for producing a carpet from a carpet precursor contacting a polymer sheet.

These and other objects and features will be apparent from the detailed descriptive material which follows.

BRIEF DESCRIPTION OF THE DRAWINGS

The figures listed below represent preferred embodiments of the invention described herein.

Figure 1 is a cross-sectional view of a carpet being manufactured in accordance with a preferred embodiment of the present invention;

Figures 2a is a cross-sectional view of a cut pile carpet precursor;

Figure 2b is a cross-sectional view of a cut pile carpet made in accordance with the teachings of the present invention;

Figure 3a is a cross-sectional view of a carpet precursor for a loop pile carpet;

Figure 3b is a cross-sectional view of a loop pile carpet made in accordance with the teachings of the present invention;

Figure 3c is a cross-sectional view of a loop pile carpet with secondary backing made in accordance with the teachings of the present invention;

Figure 4a is a side schematic view of an apparatus used in the making of carpet, employing a heated roller;

Figure 4b is a pictorial view of an apparatus of the type described generally in connection with Figure 2a;

Figures 5a and 5b are graphs illustrating the estimated temperatures of carpet components as a function of time for the apparatus of Figures 2;

Figure 6 is a side schematic view of an apparatus used in the making of carpet, employing a heated plate;

Figure 7 is a side schematic view of an apparatus used in making carpet employing a continuous, temperature-controlled surface; and

Figure 8 is a cross-sectional view of a loop pile carpet with a coated primary backing made in accordance with the teachings of one embodiment of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

According to the present invention, a thermoplastic polymer sheet is laminated with a carpet precursor to form a carpet product with desirable physical properties. Generally, the carpet precursor is made of a face yarn which interpenetrates a primary backing or grid defining the plane

of the finished carpet. The carpet precursor may be woven or knitted.

In preferred embodiments, the carpet precursor has face yarn tufted in a primary backing and integrally fused to itself. A greige goods coating of thermoplastic polyolefin polymer having recurring polar moieties is contacted with the underside of the formed carpet precursor. A carpet product with excellent physical properties may be made using the techniques and apparatus described as follows.

The carpet of the present disclosure is desirably prepared by feeding a primary carpet backing into a conventional tufting machine. During the tufting process, carpet face yarn is also fed into the tufting machine wherein hundreds of individual tufting needles may be employed to stitch through the primary carpet backing, thus forming a continuous web of face fiber tufted through the primary backing. At this point, the carpet face fiber is secured to the backing to a degree sufficient for movement of the tufted material for further processing, but not sufficient for its use as a finished carpet. The tufted fibers removed from the tufting machine are called greige goods.

The greige goods taken from the tufting machine are finished to make the material suitable for finished carpet. First, the greige goods are preferably heated to melt the tufted fibers together within the primary backing, thereby integrally fusing the tufted fibers to themselves and/or to the primary backing. After fusing the tufted fibers, a greige goods coating comprising a thermoplastic polyolefin polymer having recurring polar moieties is applied to the underside of the greige goods at a temperature sufficiently high so as to create a heat bond between the primary backing layer and/or carpet face fiber and the greige goods coating. A temperature sufficiently high to create a heat bond is a temperature at least equal to the melting temperature of the greige goods coating. More preferably, a temperature sufficiently high enough to create a bond is a temperature at least about 100°F higher than the melting point of the greige goods coating, even more preferably at least about 125°F higher, and even more preferably at least about 150°F higher than the melting point of the greige goods coating. For example, if the greige goods coating is polypropylene, a preferred temperature is at least about 450°F, more preferably at least about 475°F, even more preferably at least about 500°F. Of course, temperatures too high may

result in unwanted degradation of the polymers.

Figure 1 illustrates some of the features of a carpet product of a preferred embodiment of the present invention. A primary backing layer is designated by the numeral 10. Face yarn is tufted in the primary backing forming a yarn pile 12 on the upper side of the carpet and back loops or knots 14 on the bottom. The tufted primary backing 16 is referred to here as the carpet precursor, carpet base or greige goods. On the left-hand side of Figure 1, the carpet face yarn is loosely secured to the backing 10 by the tufting process to a degree sufficient for movement of the precursor for further processing, but the precursor is not sufficiently mechanically stable for use as a finished carpet.

The carpet precursor is desirably heated to a temperature sufficient to cause melting of the back loops such that at least a portion of substantially all of the fibers therein integrally fuse together and/or at least a portion of the back loops integrally fuse with other back loops.

The precursor is then laminated with a greige goods coating 18 in a thickness of from about 3 to 15 mils to form the carpet product 20. Advantageously, the greige goods coating is a thermoplastic polyolefin polymer having

recurring polar moieties. The carpet precursor is adhered to or integrally fused with the greige goods coating.

CARPET PRODUCTS

Figure 1 illustrates a preferred embodiment of the present invention: a carpet product including a face yarn and a backing material coated with a polymer.

More specifically, preferred embodiments of the carpet may comprise a primary backing, a face yarn protruding from a top surface of the primary backing, where the fibers of the face yarn are integrally fused, and a greige goods coating of a thermoplastic polyolefin polymer having recurring polar moieties adhered or integrally fused to the back loops of the face yarn and/or to the bottom surface of the primary backing.

The primary backing may preferably be a polypropylene woven or non-woven material wherein the fill yarn is a thermoplastic polyolefin polymer having recurring polar moieties to better facilitate adherence to or integral fusing with the inside of the fiber bundle back loop.

Alternatively, the primary backing may be coated with a thermoplastic polyolefin polymer having recurring polar

moieties before tufting. Again, this facilitates better adherence to or integral bonding between the primary backing and the inside of the fiber bundle back loop. Further, because this primary backing coating may adhere or integrally fuse with the greige goods coating, it further helps to lock the fiber bundle in place on the primary backing, preventing pull-out and fuzzing of the fibers.

The carpet product of the present invention may also include one or more secondary backing layers adhered or integrally fused to the carpet precursor by a greige goods coating. Preferably, the secondary backing comprises tape yarn in both the warp and fill direction.

The tufts of fiber protruding from the top surface of the primary backing layer may be of any of the conventionally used fibers or yarns for tufting carpet. Such materials preferably include nylon, polyester and polypropylene, or other thermoplastic synthetic materials when the fibers are to be integrally fused to themselves. However, the yarns can include any of the natural or synthetic fibers known by those skilled in the art. The fibers protruding from the primary backing may be made of the same material as the primary backing itself.

Any one or more of the face yarn, primary backing,

primary backing coating, secondary backing and greige goods coating may comprise the same thermoplastic polymer. Preferably, the thermoplastic polymer is a thermoplastic polyolefin polymer having recurring polar moieties, also termed a "polar modified polyolefin". As used herein, the phrase "thermoplastic polyolefin polymer having recurring polar moieties", or "polar modified polyolefin," is meant to include a random, impact or block copolymer, or a graft polymer. The polyolefin copolymer comprises, for example, ethylene, propylene or butylene and polar monomers including, but not limited to, methacrylate, vinyl acetate, acrylic acid, methacrylic acid, ethyl acrylate, butyl acrylate and vinyl alcohol. The graft polymers comprise, for example, polyethylene, polypropylene or polybutylene having a polar moiety grafted thereon, wherein the polar moiety is preferably maleic anhydride (MAH). Modified polypropylene as used herein is meant to include both the copolymers of propylene and graft polymers of polypropylene set forth above. A polymer of polyolefin and an acrylate as used herein is meant to include a copolymer of ethylene, propylene or butylene with one or more of methacrylate, ethyl acrylate or butyl acrylate, or a graft polymer of polyethylene, polypropylene or polybutylene with one or more of

methacrylate, ethyl acrylate or butyl acrylate. Polymers of this type are set forth in Table A of U.S. Patent No. 5,240,530, herein incorporated by reference.

In a preferred embodiment, all of the layers of the carpet comprise the same thermoplastic polyolefin polymer having recurring polar moieties. In this embodiment, all layers of the carpet integrally fuse with all other layers, forming a strong carpet product.

In another embodiment, the primary and secondary backing and greige goods coating are formed of one polymer and the face yarn is formed of a different polymer. For example, the primary and secondary backing and greige goods coating are formed of a thermoplastic polyolefin polymer having recurring polar moieties and the face yarn is formed of nylon or polyester, or of natural materials such as cotton or wool. In other embodiments, some or all of the backing may be formed from thermoplastic polyolefin polymer having recurring polar moieties. It is preferred, however, to use a polymer for the primary and secondary backings with melting points similar to that of the greige goods coating to facilitate adhesion to, or, preferably, integral fusion with the greige goods coating.

In some carpets, the bottom layer (either the greige goods coating or secondary backing) may be formed from a blend of thermoplastic polyolefin polymer having recurring polar moieties and thermoplastic elastomer to provide some properties of the elastomer such as flexibility, non-skid character and other properties similar to rubber.

The primary backing of the carpet product may include any synthetic resin that will integrally fuse with the greige goods coating and may be, for example, a woven or non-woven fabric, a film or a web. Preferably, the primary backing is made of a thermoplastic polyolefin polymer, copolymer or terpolymer in the warp direction, with a thermoplastic polyolefin polymer having recurring polar moieties in the fill direction, preferably a maleic anhydride graft polymer of polypropylene. This facilitates adhesion or integral fusion of the interior of the fiber bundle with the primary backing, helping to prevent pull-out of the fibers and making total penetration of the adhesive coating into the fiber bundle unnecessary.

Further, the primary backing may be coated with a thermoplastic polymer, such as a thermoplastic polyolefin polymer having recurring polar moieties as discussed herein throughout, before tufting of the fibers through the primary

backing. The primary backing coating is preferably in an amount of from about 0.5 to 5.0 mils thick. Coating the primary backing before tufting promotes adhesion or integral fusion of the interior of the fiber bundles with the primary backing upon heating. Again, this helps to secure the fibers in place without necessitating total penetration of the fiber bundle by the adhesive coating. Further, where the primary backing coating is exposed to the greige goods coating through the fiber back loops, adhesion or integral fusion of the primary backing coating and greige goods coating will occur, effectively trapping the fiber bundle between the primary backing coating and greige goods coating. This increases tuft bind strength of the resultant carpet.

The secondary backing material, if applied, may preferably include any synthetic resin that will adhere or integrally fuse with the greige goods coating. Advantageously, the secondary backing will comprise the same thermoplastic polyolefin polymer having recurring polar moieties as the primary backing. The secondary backing for the carpets of the present disclosure may comprise a woven or non-woven fabric. A woven secondary backing may be an open weave or leno weave, preferably having tape yarn in both the warp direction and in the fill direction. However, the open

weave is not necessary to obtain a suitable bond as may be required with use of a latex adhesive.

The greige goods coating may be formed from a thermoplastic polyolefin polymer having recurring polar moieties. A preferred greige goods coating is a copolymer of ethylene or a graft polymer of polypropylene. Preferably, the greige goods coating is applied in an amount of from about 3 to 15 mils.

The thermoplastic polyolefin polymer having recurring polar moieties used in the greige goods coating may be compounded with inert fillers by either extrusion compounding or mixing operations. Such fillers may include calcium carbonate, silicates, talc, calcium, glass fibers, carbon black and wood flour. Other fillers may also be suitable.

The use of such fillers in the greige goods coating may range from about 0.1% to as high as about 50%. At the high levels, an exceedingly stiff board like material may be made that may be used, e.g., as a trunk liner, molded floor mat or a door panel in an automobile. Because addition of a filler significantly alters the performance and process ability of the polymer, filled systems may be designed to satisfy a particular product need with minimum effect on other performance aspects.

It is desirable that, for some use applications, carpet made in accordance with the present invention pass the "pill test" (ASTM D-2859) for fire resistance. Thus, in some applications where enhanced flame resistance is required, a fire-retardant may be added to the feedstock used to produce the greige goods coating.

Optionally, blends of the thermoplastic polyolefin polymers having recurring polar moieties and thermoplastic elastomers may be used to make the greige goods coating or co-extruded layer. The thermoplastic elastomers (TPE's) are a diverse family of rubber-like materials that, unlike vulcanized rubbers, may be processed and recycled as thermoplastics. A listing of some suitable TPE's is given in parent patent U.S. Patent No. 5,240,530 at Table A, column 11, which is hereby incorporated by reference. The TPE's are not merely substitutes for thermosetting polymers, but may also replace or improve their properties. There are four general groups of TPE's that may be suitable for use in the present invention. The four general groups include polyurethanes, copolyesters, styrene block copolymers, and polyolefins. Blending the elastomer with the polyolefin polymer provides some of the properties of the elastomer at a lower cost. The compatibility is good for blends ranging

from about 10 to 97% elastomer based on the total amount of thermoplastic polyolefin polymer having recurring polar moieties and elastomer.

As a class, the TPE's may provide toughness, flexibility over a wide temperature range, and resistance to abrasion, weathering, and a variety of solvents and other chemicals. Thus, the properties of each of the materials in the group may be tailored for use in the carpet of the present invention by polymerization methods, blending, and incorporation of additives, fillers, and reinforcements to form carpets having enhanced abrasion, weathering and chemical resistance.

Depending on the material composition of each of the possible carpet layers (yarn, primary backing, primary backing coating, greige goods coating, secondary backing), various adjacent or overlapping carpet layers will adhere or integrally fuse. Integral fusion is typically achieved using chemically similar thermoplastics which melt together, while adhesion requires that the materials stick together by either chemical or mechanical means. Adhered materials typically may be separated into the component parts. Adhesion and integral fusion of the various carpet components as disclosed

may provide a carpet having improved strength, fuzz resistance and longevity.

IMPROVED METHODS AND APPARATUS FOR CARPET MANUFACTURE

With reference to Figure 1, an improved method of making a carpet product according to the invention is generally illustrated. Heat and pressure are applied (for example, by a heated roller) to the underside of the carpet precursor at location 22 sufficient to heat the underside of the carpet precursor to above the melting point of the face yarn. This preheating of the carpet precursor causes a portion of substantially all of the fibers in the back loops of the face yarn to integrally fuse together. Generally, the temperature should be about 50°F above the melting point of the face yarn, preferably at least 100°F above the melting point of the face yarn. A heated greige goods coating of thermoplastic polyolefin polymer having recurring polar moieties 18 is brought into contact with the heated carpet precursor at location 24 whereby the laminated carpet product 20 is produced. The carpet product may either be the finished carpet or subjected to further processing, e.g. application of additional backings.

Figures 2 and 3 illustrate, by way of example, two types of carpet products made in accordance with the teachings of the present invention. Figure 2 relates to a cut pile, or grass, carpet and Figure 3 relates to a loop pile carpet with optional secondary backing.

Figure 2a depicts a carpet precursor 200 from which a carpet, for example, grass carpet, is made. A woven primary backing 202 is interpenetrated by fibrillated isotactic polypropylene yarn 204 in a preferred embodiment. Cut yarn ends or tufts 206 form the pile of the carpet. The yarn is loosely secured in place by back loops 208 exposed on the underside of the carpet precursor. In this example the backing 202 is a woven fabric made of polypropylene.

Figure 2b depicts a carpet product 210 made from the carpet precursor of Figure 2a. A greige goods coating 212 of thermoplastic polyolefin polymer having recurring polar moieties has been integrally fused to the carpet precursor 200. As shown in the figure, the back loops 208 and portions of the primary backing 202 have been heat bonded (i.e., adhered or integrally fused) with the greige goods coating 212. Spaces between the primary backing 202 and the greige goods coating 212 may be larger or smaller depending on the penetration of the greige goods coating into the primary

backing during manufacture. In fact, the greige goods coating may more or less conform to the shape of the bottom surface of the primary backing and encapsulate the back loops. Thus, there may be little, if any, space between the greige goods coating and the primary backing. The underside 214 of the carpet product may be essentially flat due to the cooling contact made with the surface of a casting roller during processing.

During manufacture, the back loops 208 may be heated sufficiently for individual fibrils of the yarn to integrally fuse with each other. The preliminary heating of the carpet precursor raises the temperature of the carpet precursor above the melting point of the yarn, melting at least a portion of substantially all of the individual fibers of the yarn in the back loops such that the yarn fibers melt and flow together, integrally fusing the individual fibers to each other both within a tuft and between tufts of yarn. The heat of the greige goods coating contacting the primary backing and integrally fused fibrils of yarn also may partially melt the polymers therein sufficient to form a heat bond with the greige goods coating. This enhances the mechanical durability of the resulting carpet product. Further, the integral fusing of the fibers lessens the need

for the greige goods coating to fully wet and penetrate the back loops of yarn. The integral fusing of the fibers around the primary backing sufficiently secures the fibers in place such that the carpet material will pass the Velcro® test without complete wetting by the greige goods coating of the fiber bundles.

Preferably, the primary backing comprises a thermoplastic polyolefin polymer having recurring polar moieties in the fill direction, such that heating the carpet precursor allows the fill yarn to bond with the inside of the fiber bundle loop. A fill yarn made from thermoplastic polyolefin polymer having recurring polar moieties, preferably a graft polyolefin polymer such as maleic anhydride modified polypropylene, adheres to the innermost part of the fiber bundle back loop when heated. This provides a more secure bond between the fiber bundle back loop and the fill yarn around which it is wrapped, helping to prevent pull-out of the fibers from the primary backing. By bonding the internal part of the fiber bundle back loop to the fill yarn of the primary backing, total penetration and wetting of the back loops by the greige goods coating is no longer required to hold the fibers in place.

Alternatively, the primary backing may be coated with a primary backing coating of thermoplastic polyolefin polymer having recurring polar moieties before tufting the yarn through the backing. The primary backing coating is preferably a polypropylene graft polymer with maleic anhydride. The primary backing coating is preferably in an amount of from about 0.5 to 5.0 mils thick. Upon heating, the coated primary backing will adhere or integrally fuse to the inside of the fiber bundle back loop, preventing pull-out of the fibers and reducing the need to totally penetrate the fiber bundles with the greige goods coating to ensure sufficient tuft bond strength. Further, the primary backing coating may adhere or integrally fuse with the greige goods coating, thereby locking the fiber back loop between the two coatings, holding it securely in place (see Fig. 8).

Figure 3a depicts a carpet precursor 300 from which a level loop pile carpet is made. A woven primary backing 302 is interpenetrated by a multi-fiber face yarn or bulk continuous filament (BCF) yarn 304. Such yarn may be a twisted array of, for example, 120 small denier fibers. Yarn loops or tufts 306 form the pile of the carpet. The yarn is mechanically secured to the backing 302 by back loops 308 exposed on the underside of the carpet precursor. In this

example the BCF yarn is made of polypropylene and the backing 302 is a woven fabric also made of polypropylene.

Figure 3b depicts a carpet product 310 made from the carpet precursor of Figure 3a. A greige goods coating 312 of thermoplastic polyolefin polymer having recurring polar moieties has been integrally fused to the carpet precursor 300. As shown in the figure, the back loops 308 and portions of the backing have been heat bonded with the greige goods coating 312. As in the example of Figure 2a, some voids or spaces may occur between the greige goods coating and carpet precursor. Alternatively, the upper portion of the greige goods coating may partially or totally encapsulate the back loops.

During manufacture, the back loops 308 are preferably partially melted so that individual fibers making up the yarn are integrally fused with each other by preheating of the carpet precursor before contacting it with the hot greige goods coating. The heat of the greige goods coating may further partially melt the integrally fused fibers such that they heat bond with the greige goods coating and/or the primary backing 302. It has been observed experimentally that this improves the mechanical stability of the resulting carpet product and secures the tufts and component yarn

fibers to a sufficient degree that the carpet product can pass the Velcro® test, as explained previously herein.

Figure 3c depicts a carpet product 320 which includes an optional secondary backing 322. In this example, the secondary backing is laminated with the hot greige goods coating 312 and integrally fuses with it. Preferably, the secondary backing is a tape yarn in both the weave and fill directions. More preferably, the tape yarn is a thermoplastic polyolefin polymer having recurring polar moieties for optimal adherence to or integral fusing with the greige goods coating.

An apparatus for producing a carpet product is illustrated in Figures 4a and 4b. Carpet precursor or greige goods 430 is supplied at location 431 with the carpet pile facing downwardly. The carpet precursor is placed in contact with a heated roller 432, whereby the underside of the carpet precursor is heated. This results in heating of the back loops or knots of the carpet precursor which may be partially melted therefrom, causing the fibers of the back loops to integrally fuse. The heated carpet precursor 434 travels downstream in the apparatus for lamination with a greige goods coating 436.

The greige goods coating may be a thermoplastic polyolefin polymer having recurring polar moieties, such as a copolymer or a graft polymer. The coating may be applied as a hot extrusion such as from a die as shown in Figure 4, or as a preformed film or sheet which is heated to allow heat bonding to the carpet precursor, which preferentially is itself preheated. The greige goods coating may be heated before application to the carpet precursor, or after contact therewith.

The heated roller 432 may advantageously be a fluid or oil heated roller, although other means may be employed to uniformly heat the surface of the roller, such as electrical resistance elements. When heated fluid is employed, the fluid enters the system at 438 (while shown in Figure 4a off-center, the fluid inlet is typically at the center of the roll), is circulated in the roller 432 and exits at 440 (while shown in Figure 4a off-center, the fluid outlet is typically at the center of the roll). The oil is reheated and recirculated in a closed loop system designated generally by numeral 441. Advantageously, the system is operated to maintain the surface of the roller 432 at a uniform temperature across the width of the roller. The optimum surface temperature of the roller is dependent on a number of

variables, including the structure and composition of the carpet precursor, line speed, roller pressure and the area of the contact between the roller 432 and the carpet precursor. In the system illustrated in Figure 4, the roller 432 is 5.9 inches in diameter. The surface of the roller may be maintained between 330°F and 650°F or even higher, and preferably between 400°F and 500°F. At a line speed of about 10 feet per minute, the preferred roller surface temperature was about 400 to 450°F using certain common carpet precursors as described in greater detail in the examples below.

The roller 432 may be provided with a surface or coating which resists sticking. In the system illustrated in Figure 4, the roller 432 is wrapped with teflon tape. A doctor blade 442 may be provided to remove built-up polymer melted from the underside of the carpet precursor.

Water cooled nip roll 444 may be provided which, together with the tension in the running carpet precursor, holds the underside of the carpet precursor against the heated roller. With reference to Figure 4b, which shows some additional aspects of the apparatus of Figure 4a in perspective view, the heated roller and auxiliary rollers are designated 432' and 444', respectively. The auxiliary rollers 444' are rotatably mounted to a pivoting bar assembly

446. The pressure of the carpet precursor against the heated roller is controlled by applying pressure to the pivoting bar assembly 446 by means of hydraulic actuators 448. The pressure at nips 450 and 450' have been desirably controlled to provide a contact pressure at a tangential point between the nip rolls 450 and 450' and chill roll 432 of between 1 and 4 pounds per linear inch of width with a gap setting between the respective rolls prior to introducing the carpet precursor of between zero and one inch. The contact pressure and gap setting will depend upon the thickness and density of the carpet precursor. In the apparatus of Figure 4, the hydraulic pressure may typically be set at 460 to 480 pounds per square inch to obtain the desired contact pressure at the recited gap setting.

Referring once more to Figure 4a, the rollers 444 may be mounted so that their axes of rotation can be selectively positioned along lines 445. An additional roller 447 may be provided, whose axis of rotation may be selectively positioned along line 449. During line start-up, rollers 44 and 47 may be moved downwardly so that the path of the greige goods 430 is located out of contact with the heated roller 432, thereby preventing overheating of the greige goods as it is being threaded into the line. In addition, during

operation, the location of rollers 444 along lines 445 may be adjusted to vary the heat input into the greige goods. Thus, the heated roller temperature can be maintained constant and the wrap angle (i.e. residence time) of the greige goods adjusted for line parameter variations such as greige goods weight.

As shown in Figure 4a, the heated carpet precursor 434 travels a short distance "d" to be laminated with the greige goods coating 436. Preferably, this distance is as short as possible to minimize heat loss from the carpet precursor. The heated carpet precursor 434 preferably may contact the heated greige goods coating as it is directly extruded downwardly onto the underside of the carpet precursor. The greige goods coating is formed by forcing a thermoplastic polyolefin polymer having recurring polar moieties feedstock 451 through an extrusion die 452. In examples discussed below, the extrusion die temperature is about 510°F. Alternatively, the greige goods coating may be a preformed sheet or film made by any method known in the art, including extrusion and casting. It is desirable that the greige goods coating be above its melting temperature when it contacts the carpet precursor, advantageously 100°F or more above its melting temperature, to assure good heat bonding.

The greige goods coating and carpet precursor together pass between nip roll 454 and casting or chill roll 456. As shown in Figure 4b, the nip roller 454' may be rotatably mounted on parallel pivoting arms 458. The nip roller and pivoting arms exert a pressure against the upper side of the carpet precursor which consequently presses the greige goods coating against the casting roller 456'. A contact pressure at a tangential point between the nip roller 454 and the chill roller 456 of between 1 and 4 pounds per linear inch of width with a gap setting between the respective rolls prior to introducing the carpet precursor of between zero and one inch has been desirably utilized. The contact pressure and gap setting will depend upon the thickness and density of the carpet precursor. Advantageously, the casting roller is maintained at a controlled temperature. In the examples discussed below, that temperature is 130°F.

A carpet product 460 is produced which may be subjected to additional processing. Optionally a secondary woven backing or non-woven backing (not shown) may be simultaneously laminated to the greige goods coating 436 at the casting roll 456.

In order to control shrinking of the carpet precursor or carpet product, a tenter frame (not shown) may be employed

during the preheating and lamination operations or thereafter.

Various polymers have been extruded or laminated onto carpet precursors as greige goods coatings. In particular, trials have been conducted using polypropylene homopolymer (prime virgin 5 mils), polypropylene copolymer (recycled from shrink film), polypropylene homopolymer (recycled from fiber), and thermoplastic elastomer polypropylene blend (50/50 blend). Alternatively, other thermoplastic polyolefin polymers having recurring polar moieties, including copolymers of ethylene, propylene and butylene with polar monomers such as methacrylate, vinyl acetate, acrylic acid, methacrylic acid, ethyl acrylate, butyl acrylate and vinyl alcohol, or graft polymers of polyethylene, polypropylene and polybutylene with polar moieties such as maleic anhydride, may be used as greige goods coatings. In all the trials, the extruded sheet exhibited good bonding strength to the back of the carpet. The greige goods used in the trials included a polypropylene primary backing with polypropylene face fiber and a polypropylene primary backing with nylon face fiber. In addition, certain carpet trials included a secondary backing of woven polypropylene. The secondary backing was

found to exhibit good adhesion with all the polymer types listed.

The extrusion trials were conducted with a 1.5 inch diameter, 24:1 (barrel length to diameter ratio) Sterling extruder. The extruder had a 20 horsepower DC drive and a single stage screw. The extruder was equipped with three heating zones, a screen pack collar and a pressure gauge. Speed was controlled by a variable resistor dial and a tachometer was connected to an RPM dial for speed indication. Typical extruder temperatures range from 340°F to 600°F and pressures from 1000-3000 psi. Typical die melt temperatures range from 450-580°F.

The apparatus used in the examples described below included a heated roller of the type shown in Figure 4. In that apparatus, the die width was 12 inches. The molten polymer from the die was deposited on a water cooled casting roll (7.9 inch diameter, 13 inch width). Water was passed through helical passages within the casting roll at high velocity to cool the casting roll as required. The nip roll was 3 inches in diameter. The casting roll assembly was driven by an eddy current clutch and a 1.5 horsepower motor.

While speeds of 10 feet per minute were actually used in the examples described below, it is contemplated that higher

speeds would be used in commercial production. In particular, since there is no drying step, speeds of 100 to 300 feet per minute appear possible. Carpet widths of 12 to 15 feet may be produced. Such speeds and widths require appropriate material and handling capability to move large rolls in and out of the process quickly. Thus, in contrast to conventional processes, the factor limiting line speed may be material handling and not the conventional adhesive drying step, which is eliminated in the practice of the present method.

Figure 5a presents a calculated temperature profile for the apparatus of Figure 4 in graphical form. Temperature is represented on the vertical axis; time/position is represented on the horizontal axis. Trace 500 represents the back loop temperature at various points in the process designated by letters A though E which correspond to similarly labeled locations in the apparatus of Figure 4(a). Trace 504 represents the carpet face temperature at the points A though E of Figure 4(a). The dotted line 504 represents the melting temperature of the back loop yarn. Figure 5a illustrates a temperature profile in which the back loops are maintained above their melting temperature, while

the temperature of the carpet face always remains below the melting temperature.

The temperature of the carpet product at various depths (w) as a function of time (processing stage) was simulated. Figure 5b is an example of such a simulation, and contains plots of temperature at three depths, w1, w2 and w3, which are respectively 2 mils, 6 mils and 14 mils into the backside of the carpet base. The simulation is based on the following assumed properties and parameters:

Material =	polypropylene; mp 325°F
Line Speed =	20 ft per minute
Ambient temperature =	90°F
Temp. of melt at extrusion die =	480°F
Temp. of casting roller =	100°F
Temp. of heated roller surface =	420°F
Cast roller diameter =	5.9 ft.
Cast roller wrap angle =	200°
Heated roller diameter =	5.9 ft.
Heated roller wrap angle =	220°

The times indicated as A, B and C correspond to the similarly labeled locations in the apparatus of Figure 4a. More

specifically, time A corresponds to t=o, time B corresponds to t=t (the time at which the carpet base leaves the heated roller), and time C corresponds to $t=t_2$ (the time when the extruded sheet first comes into contact with the carpet base). The time t_3 is the time when the carpet product leaves the cast roller.

The following table presents a summary of simulations, including the simulation described in connection with Figure 5(b), which is labeled Example 5 in the table.

	Coating Thickness	Heated Teflon Coated Roll Temp	Wide Angle on Prefuse	Time t_1	Time t_2	Time t_3	Prefusion Temp. (°F) Between $t>$, t, and $t>t_2$ Point			Temp. After (t2) (Maximum) (°F.) Point			Temp. at (t3) (°F) Point		
Ex.	(mils)	(°F.)	Roll	(sec.)	(sec.)	(sec.)	w1	w2	w3	w1	w2	w3	w1	w2	w3
1	10	120	90	1.158	2.658	5.233	120	<120	<120	390	300	220	250	240	205
2	10	420	90	1.158	2.658	5.233	400	350	260	450	400	305	270	260	<260
3	--	420	90	1.158	2.658	5.233	400	350	260	No Extruded Sheet			155	149	129
4	5	420	90	1.158	2.658	5.233	400	350	260	430	370	275	195	205	205
5	5	420	220	2.832	4.332	6.906	405	380	320	430	380	320	195	215	230

Examples 1 and 2 compare a simulated process with and without heat being applied to the heated roller. Example 3 illustrates the effect on the simulation of eliminating the greige goods coating. Examples 4 and 5 employ a 5 mil

extruded coating and compare the process for a heated roll wrap angle of 90° (Example 4) and 220° (Example 5). Examples 1-4 have a cast roller wrap angle of 90°. As indicated above, Example 5 has a cast roller wrap angle of 200°.

The examples illustrate how process parameters may be used to control the internal temperatures of the carpet product at various depths to achieve melting of yarn fibers and integral fusing of yarn fibers with each other and with the greige goods coating and primary backing, without thermally degrading the face yarn or primary backing during processing.

The carpet base of preferred embodiments of the present invention is a woven polypropylene primary carpet backing. This backing is woven from polypropylene tapes (tape thickness 1.0 to 2.0 mils). Preferably, one tape is a modified tape of thermoplastic polyolefin polymer having recurring polar moieties, preferably in the fill direction. The thermoplastic polyolefin polymer having recurring polar moieties may consist of an ethylene, propylene or butylene copolymer, or graft polymer of polyethylene, polypropylene or polybutylene. Preferably, the modified tape is a graft

polymer of polypropylene and maleic anhydride. The tapes are machine direction oriented to arrive at tensile strengths in the range of about 4 to 6 grams per denier. Orientation of the thermoplastic polyolefin polymer involves organization of the crystalline structure by controlled handling and cooling during production. This process makes it possible to make the backing strong enough for the end carpet use. However, the backing cannot be heated for too long to a temperature above the original orientation temperature (240 to 280°F) without damaging the orientations of the thermoplastic polyolefin polymer. If the orientation is lost substantially throughout the tape thickness, the strength of the backing is compromised.

It will be clear from the foregoing that variable wrap angles may be used at a constant line speed to change the internal carpet temperatures without changing the apparatus temperature settings or the process speed. The process response to a wrap angle change is relatively instantaneous. The process response to apparatus temperature setting and line speed changes is much slower (i.e., it takes

a relatively long time to reach the desired equilibrium process temperature at points w1, w2, and w3).

This feature is very important, particularly for a commercial carpet manufacturer who must routinely make many varieties of carpet (e.g. often the same carpet style will be offered in one color line but at three different face fiber weights or qualities). In such cases, adjustment of the wrap angles can provide the necessary heat adjustment (to accommodate the three different face weights) on the fly. Likewise, adjustment of wrap angles may facilitate start-up of a line and avoid burning through the carpet base when the line runs initially at a slow speed.

While adjustment of line speed and process temperature settings may be used, the temperatures w1, w2 and w3 reach equilibrium much more slowly and involve more complicated interactions.

Figure 6 is a schematic side view of an alternative embodiment of the present invention. The underside of a carpet precursor 600 is passed in contact with an electrically heated plate 602. The carpet precursor 600 may be pressed between the electrically heated plate 602 and a

second plate 604 whose temperature is not controlled. Preferentially, electrically heated plate 602 is oriented at an angle with respect to second plate 604 in order to gradually increase the pressure exerted on the carpet precursor and iron the back loops as the carpet precursor moves from right to left across the electrically heated plate 602. Successful trials of the apparatus have been run where the surface temperature of the plate 604 was set at 600°F. Alternatively, a radiant heater (not shown) may be substituted for the heated plate 602.

With continuing reference to Figure 6, heated carpet precursor 606 is drawn to the nip 607 formed between nip roller 608 and casting roller 610. A greige goods coating 612 is extruded directly onto the underside of the heated carpet precursor from extrusion die 614. Casting roll temperatures between 80 and 120°F have been employed. Pressures of between 50 to 70 psi at the nip 607 have been employed.

Temperature variations across the heated plate 602 have been observed to produce variation across the width of the carpet product. Cool areas produce regions in loop pile

BCF carpet, for example, which fail the Velcro® test. Hot areas produce regions of apparent excess shrinkage and face yarn damage. In addition, the hot areas may deposit excessive melted polymer from the greige goods coating onto the heated plate.

Figure 7 is a schematic side view of another embodiment of the present invention. In Figure 7, a carpet precursor 700 is supplied to the apparatus, pile side down. A sheet 702 of greige goods coating is also supplied to the apparatus. The sheet 702 may either be freshly extruded in a manner similar to that described above, or it may be formed at a different time and/or location and supplied from a feed roll.

The apparatus of Figure 7 includes a first differentially heated and cooled surface 704. The surface functions both as a heated surface for integrally fusing the greige goods coating sheet 702 to the carpet precursor 700 and as a casting surface for forming and cooling the underside of the carpet product.

In preferred embodiments of the present invention, the surface 704 is a continuous belt which travels around

heated cylinder 706 and cooled cylinder 708. Stationery heating and cooling units 710 and 712, respectively, may also be provided to adjust the temperature profile around the path of travel of the belt 714.

In operation, the belt is differentially heated so that it is relatively hot at location 714 where it first contacts the greige goods coating sheet 702. At a downstream location 716, the heated greige goods coating sheet contacts the carpet precursor, the combination of which is moved and cooled as the belt travels from left to right in Figure 7.

A lower continuous belt system 718 may be provided for applying pressure to the upper side of the carpet product. An upper surface 720 of the lower belt may be oriented at an angle with respect to the upper belt as illustrated in order to gradually increase the pressure exerted on the carpet product. The temperature of the lower belt 718 may also be controlled in a manner similar to belt 704, albeit at lower temperatures.

At location 722, the carpet product and belt are sufficiently cool that the carpet product readily separates

from the belt without leaving significant amounts of melted polymer (preferably no melted polymer) on the belt 704. From this location the carpet product travels downstream in the production line.

Figure 8 is a cross-sectional view illustrating a carpet and carpet-making process in accordance with a more preferred embodiment of the present invention. In the Figure, processing distances have been compressed for illustration purposes, and processing steps illustrated schematically. Though this process is shown as a continuous process, it will be understood that various steps may be performed on different manufacturing lines at different times. The illustrated process begins with a primary backing 800 (shown here as a woven primary carpet backing with warp strands 802 and fill strands 804). Advantageously the primary backing is made of thermoplastic polyolefin polymer having recurring polar moieties.

A thermoplastic primary backing coating 806 may be applied to the primary backing 800. This layer may be omitted in some embodiments. Preferably, the primary backing coating 806 is produced by extruding a thermoplastic

polyolefin polymer having recurrent polar moieties onto one side of the primary backing 800 from extruder 808. Yarn 810 interpenetrates the coated primary backing 812. Advantageously, the yarn may be a nylon multi-filament yarn. The yarn is tufted, looped or punched through the coated primary backing to form back loops such as 814.

At the indicated location, pressure and/or heat may be applied to the product. This process may be performed by the heated roller systems described above. Where the yarn is multi-filament yarn, at least a portion of the back loop will be heated above the melting point of the yarn material so that at least a portion of substantially all of the filaments integrally fuse to one another. If the yarn is nylon, this may require temperatures in the range of 520°F to 550°F. Because the yarn is typically twisted, it will be understood that this step may require heating only a portion (for example about 50%) of the thickness of the yarn to a temperature and pressure sufficient to affect integral fusing.

At a point later in the process, a second thermoplastic layer, or greige goods coating, 816 is applied

to the carpet product. In a preferred embodiment, this layer is produced by extruding a second thermoplastic polyolefin polymer having recurrent polar moieties onto the carpet base 812 from extruder 818. The greige goods coating may be extruded in hot, essentially molten, form directly onto the carpet product while the carpet base is still hot from the heating and pressing step.

The end product of various of the processing steps depicted in Figure 8 may have some or all of the following advantageous features:

(1) Integrally fused filaments (such as nylon filaments) in the back loops of the yarn, whereby the finished carpet resists fuzzing.

(2) A primary backing 800 of thermoplastic polyolefin polymer (especially one having recurring polar moieties) integrally fused or adhered with the primary backing coating 806 such as at interface 820.

(3) A primary backing 800 of thermoplastic polyolefin polymer (especially one having recurring

polar moieties) integrally fused or adhered with the integrally fused filaments in the back loops 814.

(4) A primary backing coating of thermoplastic polyolefin polymer having recurring polar moieties adhered or integrally fused to inner portions of carpet back loops, such as at interface 822.

(5) Pressure flattened back loops such as at 824 onto which further layers or backings may readily be applied. The back loops themselves may be integrally fused to one another.

(6) A greige goods coating 816 adhered or integrally fused to the lower portions of the back loops and/or the primary backing coating 806 such as at interface 826.

(7) A greige goods coating 816 integrally fused or adhered to portions of the primary backing 800 and/or primary backing coating 806 such as at interface 828.

(8) An extruded and cast greige goods coating 816 to which further layers or backings may be readily adhered or integrally fused.

One product of the foregoing process is a durable carpet with nylon face yarn and a flexible, rollable polyolefin based backing which has physical properties described in the art as a "good hand."

EXAMPLES

The process parameters for preparing the carpet products of the following inventive Example 1 and Comparative Example appear in the following table.

	Example 1	Comparative Example 2
Extrusion Temp. (°F)	600	575
Back Pressure (psi)	430	710
Greige Goods Coating Thickness (mils)	10	10
Nip Pressure (psi)	90	80
Drum Temp. (°F)(hot oil)	475	Not Applicable
Face Fiber	nylon	nylon
Greige Goods Coating Material	modified poly-propylene	ethylene methacrylate (EMA)
Velcro Test Result	very good; little to no fuzz	fair to poor; moderate to heavy fuzz

EXAMPLE 1

A sample of carpet of the present disclosure was prepared according to the methods described herein. In particular, a nylon face fiber was tufted on a primary backing, to form a carpet precursor. The back side of the formed carpet precursor was heated on a hot oil drum at a temperature of 475°F to pre-fuse the nylon face fibers to themselves. A greige goods coating of a polypropylene graft polymer with maleic anhydride manufactured by Morton Chemical under the name of Tymor 212599-2 was extruded in molten form from a die at a temperature of 600°F onto the pre-fused carpet precursor at a thickness of 10 mils. The coated carpet precursor was then run through a nip roll at a nip

pressure of 90 psi and a back pressure of 430 psi before cooling. A Velcro test performed 24 hours after formation of the carpet product indicated a very good bond with little to no fuzzing, indicative of integral fusing of the nylon fibers to themselves and good adhesion or integral fusing between each of the greige goods coating, primary backing and fused fibers.

COMPARATIVE EXAMPLE

This example was prepared using a nylon face fiber and a greige goods coating of ethylene methacrylate (EMA) (24% methacrylate content) provided by Exxon. This sample was not pre-fused or pre-heated. After tufting, the carpet precursor was contacted with the greige goods coating extruded at a temperature of 575°F to a thickness of 10 mils. The nip pressure was 80 psi, and the back pressure was 710 psi. The Velcro test, performed 24 hours after formation of the carpet product, resulted in moderate to heavy fuzz, with large numbers of individual fibers being pulled out of the carpet product.

EXAMPLE 2

A carpet is made having a nylon face fiber and a primary backing of polypropylene in the warp direction and maleic anhydride graft polypropylene polymer in the fill direction. Upon preheating to a temperature of about 460-550°F, portions of substantially all of the nylon fibers integrally fuse together, and the fill yarn adheres to the inside portion of the nylon fiber back loop. The pre-fused carpet precursor is coated with about 10 mils of extruded maleic anhydride graft polypropylene polymer and cooled. The greige goods coating integrally fuses to at least the fill yarn of the primary backing and adheres to the nylon fibers. The carpet thus made will have little to no fuzz and a high tuft pull strength.

EXAMPLE 3

A carpet is made having a nylon face fiber and a primary backing of polypropylene coated on one side with a primary backing coating of ethylene methacrylate. Upon preheating to a temperature of about 460-550°F, portions of substantially all of the nylon fibers integrally fuse

together, and the primary backing coating adheres to the inside portion of the nylon fiber back loop. The preheated carpet precursor is coated with about 10 mils of extruded ethylene methacrylate and cooled. The greige goods coating integrally fuses to at least the primary backing coating and adheres to the nylon fibers. The carpet thus made will have little to no fuzz and a high tuft pull strength.

As shown by the above Examples, the most preferred embodiments of the invention described herein are as follows:

(1) A carpet having a primary backing, preferably of polypropylene, a face yarn made up of a plurality of nylon fibers tufted in the primary backing so that back loops of yarn are on the underside of the primary backing, wherein the nylon fibers are integrally fused together by pre-heating, and a greige goods coating of a thermoplastic polyolefin polymer having recurring polar moieties, preferably a maleic anhydride graft polymer of polypropylene, applied to the carpet precursor after pre-heating so that the greige goods coating adheres to one or more of the integrally fused fibers and primary backing.

(2) A carpet having a primary backing wherein the fill yarn is a thermoplastic polyolefin polymer having recurring polar moieties, preferably a maleic anhydride graft polymer of polypropylene, a face yarn made up of a plurality of nylon fibers tufted in the primary backing so that back loops of yarn are on the underside of the primary backing, and a greige goods coating of thermoplastic polyolefin, wherein the fill yarn adheres to the inside of the nylon fiber back loop.

(3) A carpet having a primary backing coated with a thermoplastic polyolefin polymer having recurring polar moieties, preferably ethylene methacrylate, a face yarn made up of a plurality of nylon fibers tufted in the primary backing so that back loops of yarn are on the underside of the primary backing, and a greige goods coating of thermoplastic polyolefin, preferably of the same composition as the primary backing coating, wherein the inside of the back loops of the face yarn adheres to the primary backing coating, and the primary backing coating and greige goods coating integrally fuse, locking the yarn fibers in place.

From the foregoing description, one of ordinary skill in the art can ascertain the essential characteristics of the present invention, and without departing from the spirit and scope thereof, can make changes and modifications of the disclosed techniques to adapt them to various uses and conditions. As such, these changes and modifications are properly within the scope of the range of equivalents of the following claims.

WE CLAIM:

1. A carpet comprising:

a primary backing;

a yarn made up of a plurality of thermoplastic fibers, said yarn being tufted in said primary backing and having back loops on the underside of the primary backing, wherein a portion of substantially all of the plurality of fibers of the yarn in said back loops is integrally fused together; and

a greige goods coating of a thermoplastic polyolefin polymer having recurring polar moieties which contacts one or more of said integrally fused fibers and said primary backing.

2. The carpet of claim 1, wherein the greige goods coating is a copolymer of propylene, ethylene or butylene with a polar moiety selected from the group consisting of methacrylate, vinyl acetate, acrylic acid, methacrylic acid, ethyl acrylate, butyl acrylate and vinyl alcohol.

3. The carpet of claim 1, wherein the greige goods coating is a graft polymer of polypropylene, polyethylene or polybutylene with a polar moiety.

4. The carpet of claim 1, wherein the plurality of fibers is integrally fused at a temperature at least 50°F greater than the melting point of the fibers.

5. The carpet of claim 1, wherein the plurality of fibers is integrally fused at a temperature at least 100°F greater than the melting point of the fibers.

6. The carpet of claim 1, wherein the primary backing comprises polypropylene.

7. The carpet of claim 6, wherein the primary backing comprises propylene copolymer or polypropylene graft polymer in either a warp or a fill direction which adheres to the integrally fused fibers.

8. The carpet of claim 6, wherein the primary backing comprises propylene copolymer or polypropylene graft polymer in either a warp or a fill direction which integrally fuses to the integrally fused fibers.

9. The carpet of claim 1, wherein the yarn is nylon bulk continuous fiber yarn, the primary backing is a thermoplastic polyolefin polymer, and the greige goods coating is an extruded sheet comprising a copolymer of ethylene, propylene or butylene and a polar acrylate.

10. The carpet of claim 1, wherein the primary backing is coated with a primary backing coating comprising a thermoplastic polyolefin polymer having recurring polar moieties before said yarn is tufted in said primary backing,

and wherein said tufted yarn integrally fuses or adheres to the coated primary backing.

11. The carpet of claim 10, wherein the primary backing coating is 0.5-5.0 mils thick.

12. The carpet of claim 10, wherein the primary backing coating comprises a graft polymer of polypropylene and maleic anhydride.

13. The carpet of claim 1, further comprising a second backing adhered or integrally fused to the greige goods coating such that the greige goods coating is between the primary backing and second backing.

14. The carpet of claim 13, wherein the second backing comprises polyolefin tape yarn in both warp and fill directions.

15. The carpet of claim 1, wherein the greige goods coating adheres to one or more of the integrally fused fibers and the primary backing.

16. The carpet of claim 1, wherein the greige goods coating integrally fuses to one or more of the integrally fused fibers and the primary backing.

17. The carpet of claim 1, wherein the greige goods coating is between 3 and 15 mils in thickness, and wherein upper portions of the coating surround said back loops.

18. The carpet of claim 1, wherein the yarn fibers are selected from the group consisting of nylon, polypropylene, polyester, polyethylene, acrylic and a combination thereof.

19. The carpet of claim 1, wherein the carpet has a tuft bind strength of at least 4 pounds.

20. A carpet which comprises:

a primary backing having a primary backing coating of a thermoplastic polyolefin polymer having recurring polar moieties;

a face yarn made of a plurality of fibers in a fiber bundle, said yarn being tufted in said coated primary backing and having back loops on the underside of the coated primary backing, wherein the fiber bundle contacts the coated primary backing; and

a greige goods coating comprising a thermoplastic polyolefin polymer which contacts one or more of said fiber back loops and coated primary backing.

21. The carpet of claim 20, wherein the fiber bundle adheres or integrally fuses to the coated primary backing.

22. The carpet of claim 20, wherein the plurality of fibers of the yarn in said back loops is integrally fused.

23. The carpet of claim 22, wherein the plurality of fibers is integrally fused at a temperature at least 50°F greater than the melting point of the fibers.

24. The carpet of claim 22, wherein the plurality of fibers is integrally fused at a temperature at least 100°F greater than the melting point of the fibers.

25. The carpet of claim 20, wherein the primary backing comprises polypropylene.

26. The carpet of claim 20, wherein the primary backing coating is 0.5-5.0 mils thick.

27. The carpet of claim 20, wherein the primary backing coating comprises a graft polymer of polypropylene and maleic anhydride.

28. The carpet of claim 20, further comprising a second backing such that the greige goods coating is between the primary backing and second backing.

29. The carpet of claim 28, wherein the second backing comprises polyolefin tape yarn in both the warp and fill directions.

30. The carpet of claim 20, wherein the greige goods coating adheres to one or more of the fiber back loops and the coated primary backing.

31. The carpet of claim 20, wherein the greige goods coating integrally fuses to one or more of the fiber back loops and the coated primary backing.

32. The carpet of claim 20, wherein the greige goods coating is a thermoplastic polyolefin polymer having recurring polar moieties.

33. The carpet of claim 20, wherein the greige goods coating is between 3 and 15 mils in thickness, and wherein upper portions of the greige goods coating surround said back loops.

34. The carpet of claim 20, wherein the yarn fibers are selected from the group consisting of nylon, polypropylene, polyester, polyethylene, acrylic and a combination thereof.

35. The carpet of claim 20, wherein the carpet has a tuft bind strength of at least 4 pounds.

36. A carpet comprising:

a primary backing;

a yarn made up of a plurality of thermoplastic fibers, said yarn being tufted in said primary backing and having back loops on the underside of the primary backing;

a greige goods coating of a thermoplastic polyolefin polymer which contacts one or more of said plurality of fibers and said primary backing,

wherein said primary backing comprises polypropylene tape in one direction, and a tape of thermoplastic polyolefin polymer having recurring polar moieties in a second direction.

37. The carpet of claim 36, wherein the tape of thermoplastic polyolefin polymer having recurring polar moieties is a polypropylene graft polymer or propylene copolymer.

38. The carpet of claim 36, wherein the tape of thermoplastic polyolefin polymer having recurring polar moieties is a maleic anhydride graft polymer of polypropylene.

39. The carpet of claim 36, wherein the tape of thermoplastic polyolefin polymer having recurring polar moieties is in a fill direction.

40. A method of making a carpet comprising:

tufting a primary backing with yarn to form a carpet base with portions of the yarn protruding from the upper side

of the primary backing and with back loop portions of the yarn exposed on the underside of the primary backing;

heating the underside of the carpet base to heat the back loop portions of the yarn sufficient to integrally fuse the individual fibers of the yarn together;

applying a greige goods coating of a thermoplastic polyolefin polymer having recurring polar moieties onto the underside of the carpet base, whereby said greige goods coating adheres to fibers in the back loops.

41. The method of claim 40, wherein the yarn, greige goods coating and primary backing are integrally fused.

42. The method of claim 40, wherein the greige goods coating is 3 to 15 mils thick.

43. The method of claim 40, wherein the primary backing comprises polypropylene.

44. The method of claim 43, wherein the primary backing comprises propylene copolymer or polypropylene graft polymer in one or more of a warp or a fill direction and is adhered to the integrally fused fibers.

45. The method of claim 43, wherein the primary backing comprises propylene copolymer or polypropylene graft polymer in one or more of a warp or a fill direction and is integrally fused to the integrally fused fibers.

46. The method of claim 40, further comprising contacting a second backing to the greige goods coating such that the greige goods coating is between the primary backing and second backing.

47. The method of claim 46, wherein the second backing comprises polyolefin tape yarn in both the warp and fill directions.

48. The method of claim 40, wherein the carpet has a tuft bind strength of at least 4 pounds.

49. The method of claim 40, wherein the yarn fibers are selected from the group consisting of nylon, polypropylene, polyester, polyethylene, acrylic and a combination thereof.

50. A method for manufacturing a carpet comprising;

coating a primary backing with a primary backing coating of a thermoplastic polyolefin polymer having recurring polar moieties;

fixing tufts of carpet fibers to the coated primary backing so that the tufts protrude from the top surface of the coated primary backing to form a tufted base and back loop portions of the carpet fibers are exposed on the underside of the primary backing;

applying a greige goods coating of a thermoplastic polyolefin polymer to at least one of the coated primary backing or back loops.

51. The method of claim 50, further comprising the step of applying a second backing such that the greige goods coating is between the primary backing and second backing.

52. The method of claim 51, wherein the second backing comprises polyolefin tape yarn in both the warp and fill directions.

53. The method of claim 50, wherein the carpet has a tuft bind strength of at least 4 pounds.

54. The method of claim 50, wherein the step of applying the greige goods coating integrally fuses the greige goods coating to one or more of the fiber back loops and the coated primary backing.

55. The method of claim 50, wherein the primary backing coating is 0.5-5.0 mils thick.

56. The method of claim 50, wherein the primary backing coating comprises a graft polymer of polypropylene and maleic anhydride.

57. The method of claim 50, wherein the yarn fibers are selected from the group consisting of nylon, polypropylene, polyester, polyethylene, acrylic and a combination thereof.

58. The carpet of claim 50, wherein the greige goods coating is a thermoplastic polyolefin polymer having recurring polar moieties.

59. The method of claim 50, further comprising integrally fusing the fibers to themselves.

60. The method of claim 59, wherein the fibers are integrally fused at a temperature at least 50°F greater than the melting point of the fibers.

61. The method of claim 60, wherein the fibers are integrally fused at a temperature at least 100°F greater than the melting point of the fibers.

62. A method of making a carpet comprising:

forming a primary baking comprising a polypropylene tape in one direction and a tape of thermoplastic polyolefin polymer having recurring polar moieties in the other direction;

tufting the primary backing with yarn to form a carpet base with portions of the yarn protruding from the upper side of the primary backing and with back loop portions of the yarn exposed on the underside of the primary backing; and

applying a greige goods coating of a thermoplastic polyolefin polymer to the underside of the carpet base,

whereby said greige goods coating adheres to the fibers of the back loops.

Fig. 1

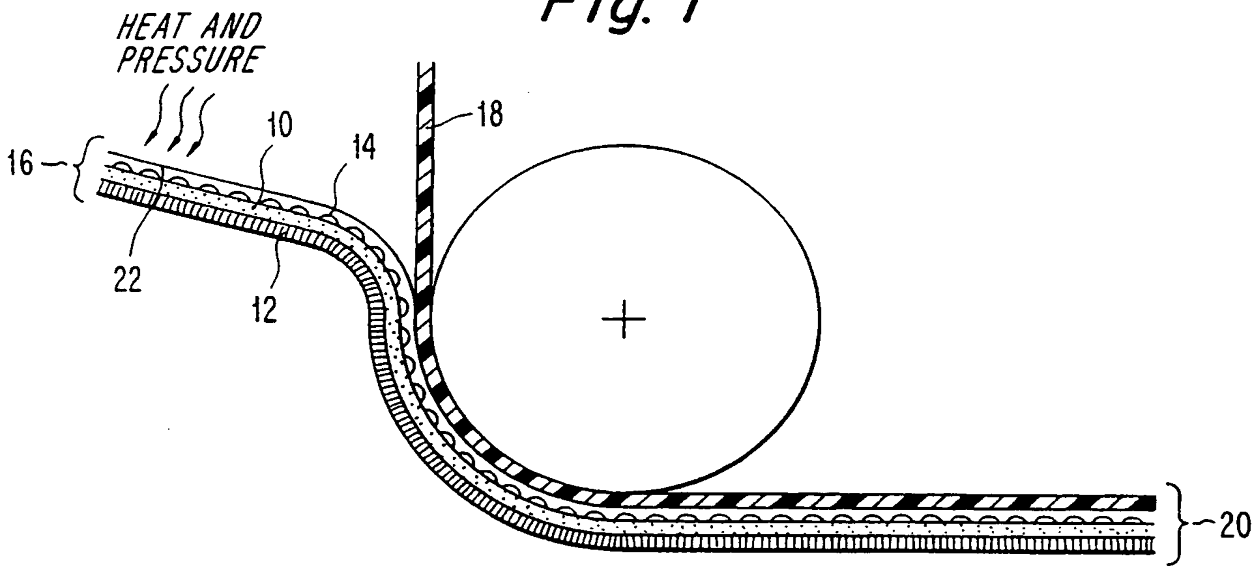
HEAT AND
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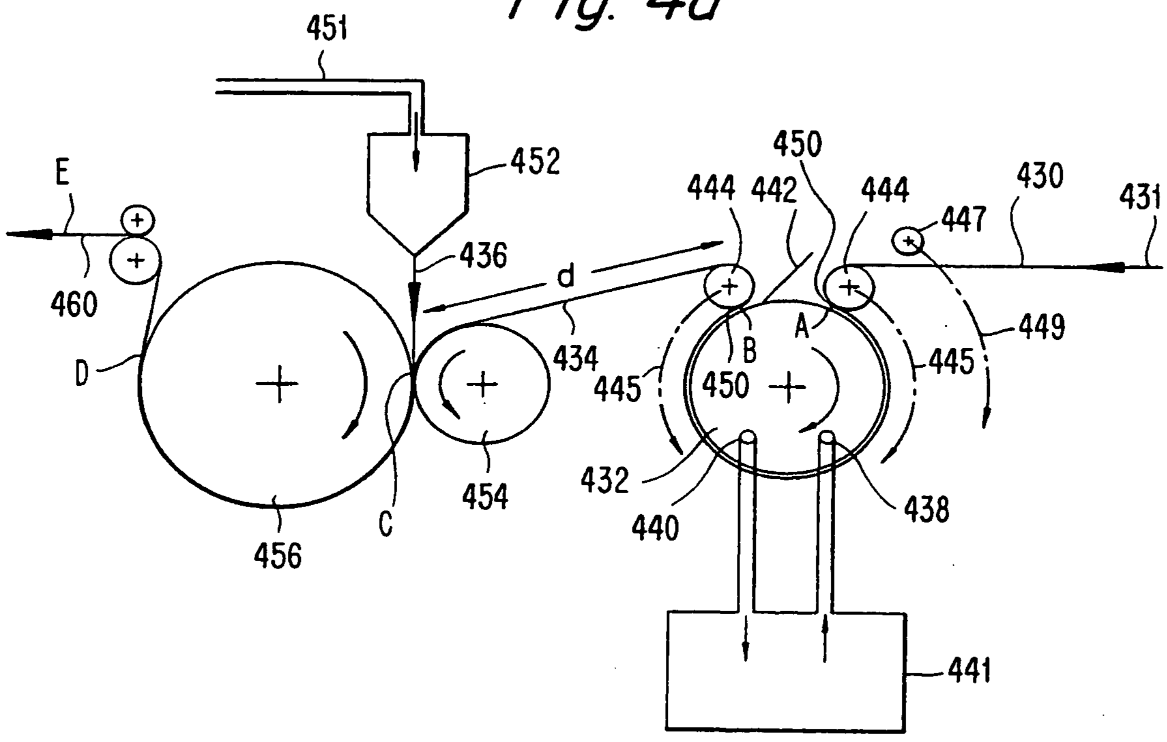
Fig. 4a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C
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Fig. 2a

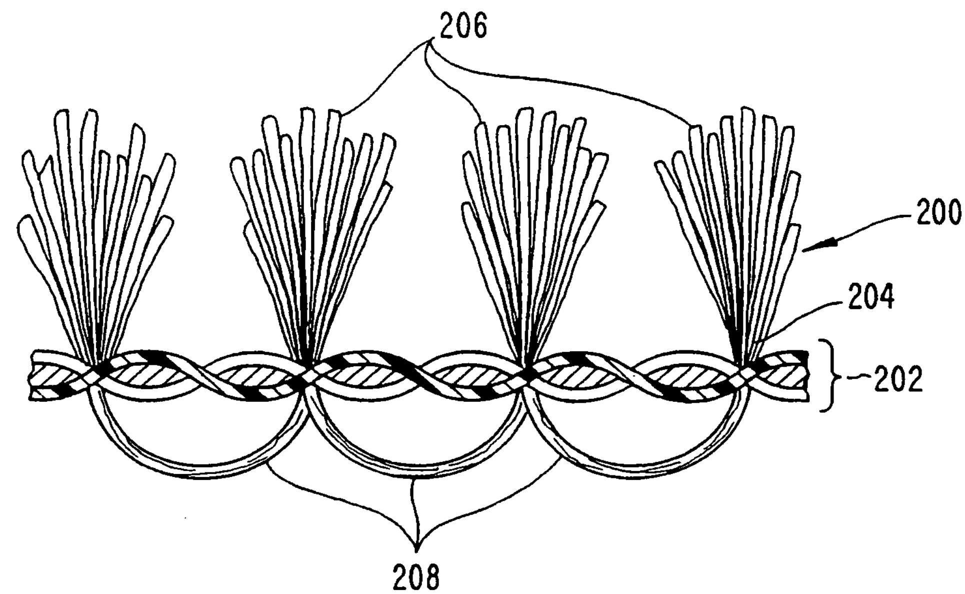

Fig. 2b

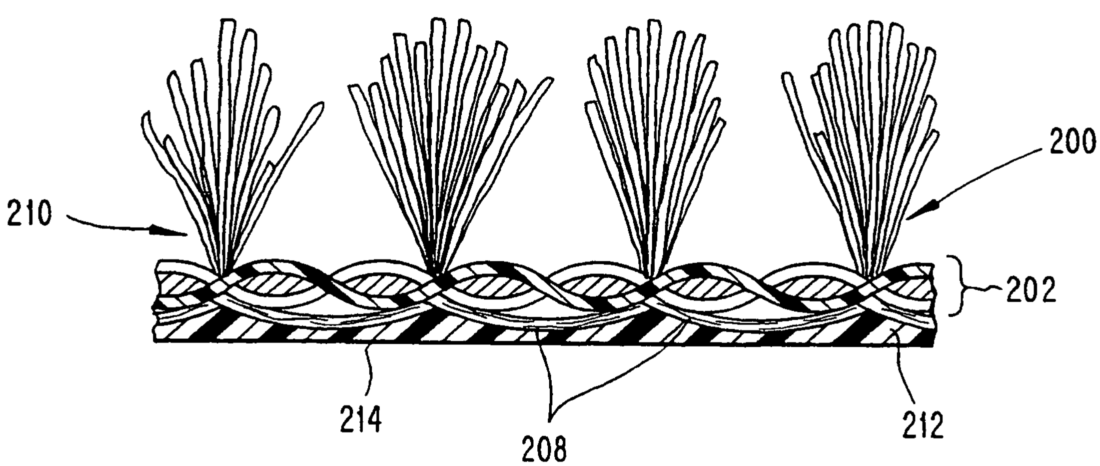

Fig. 3a

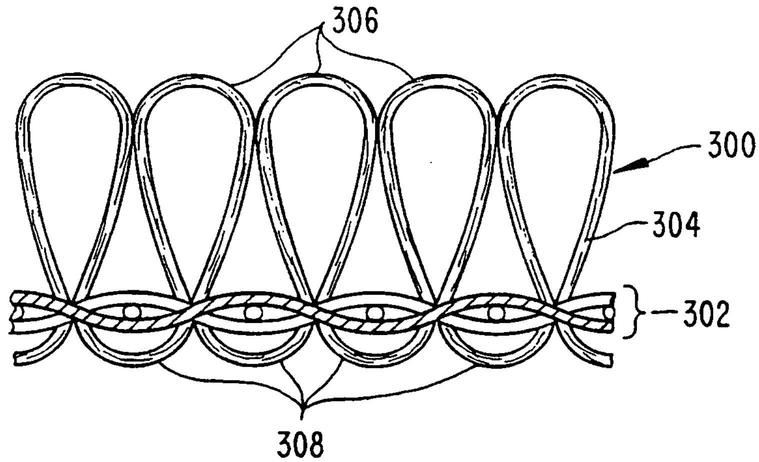

Fig. 3b

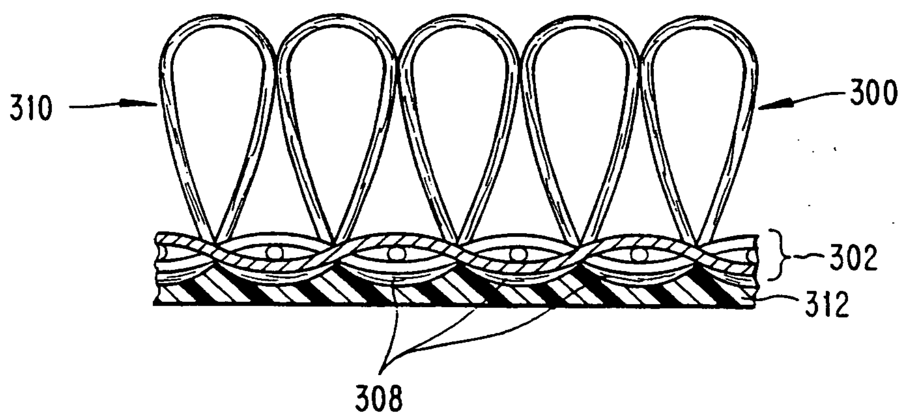

Fig. 3c

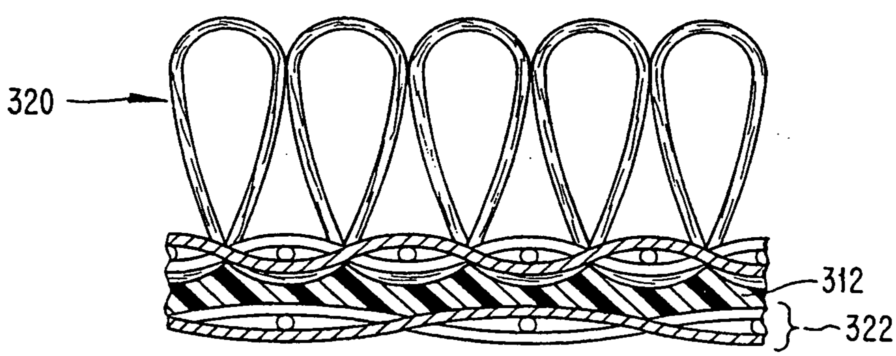

Fig. 4b

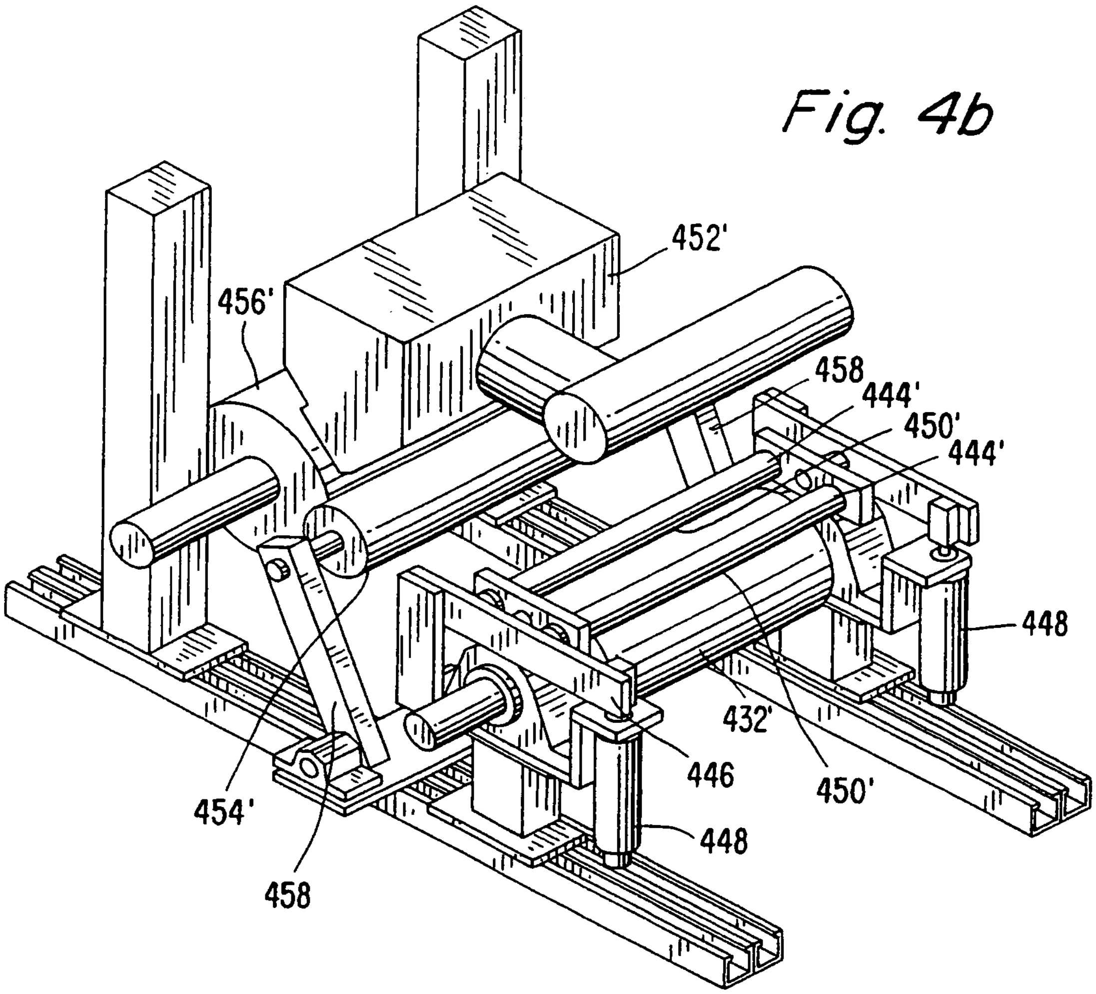
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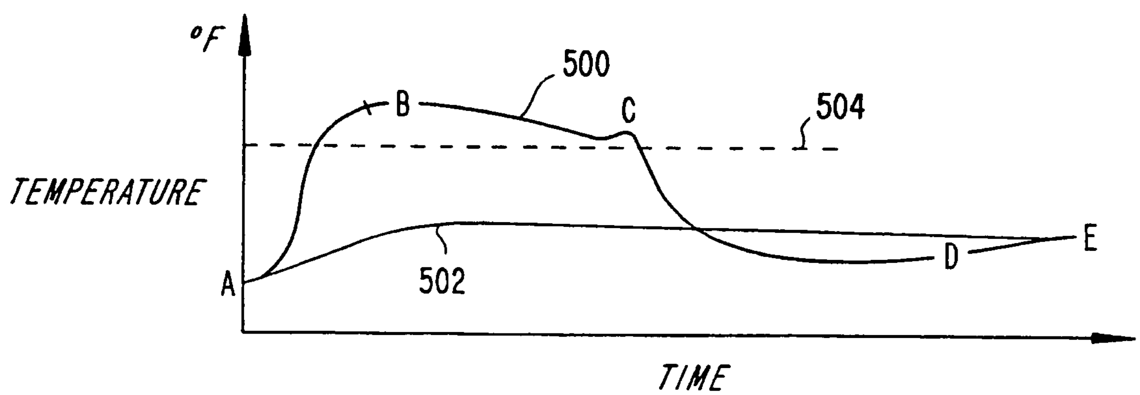
Fig. 5a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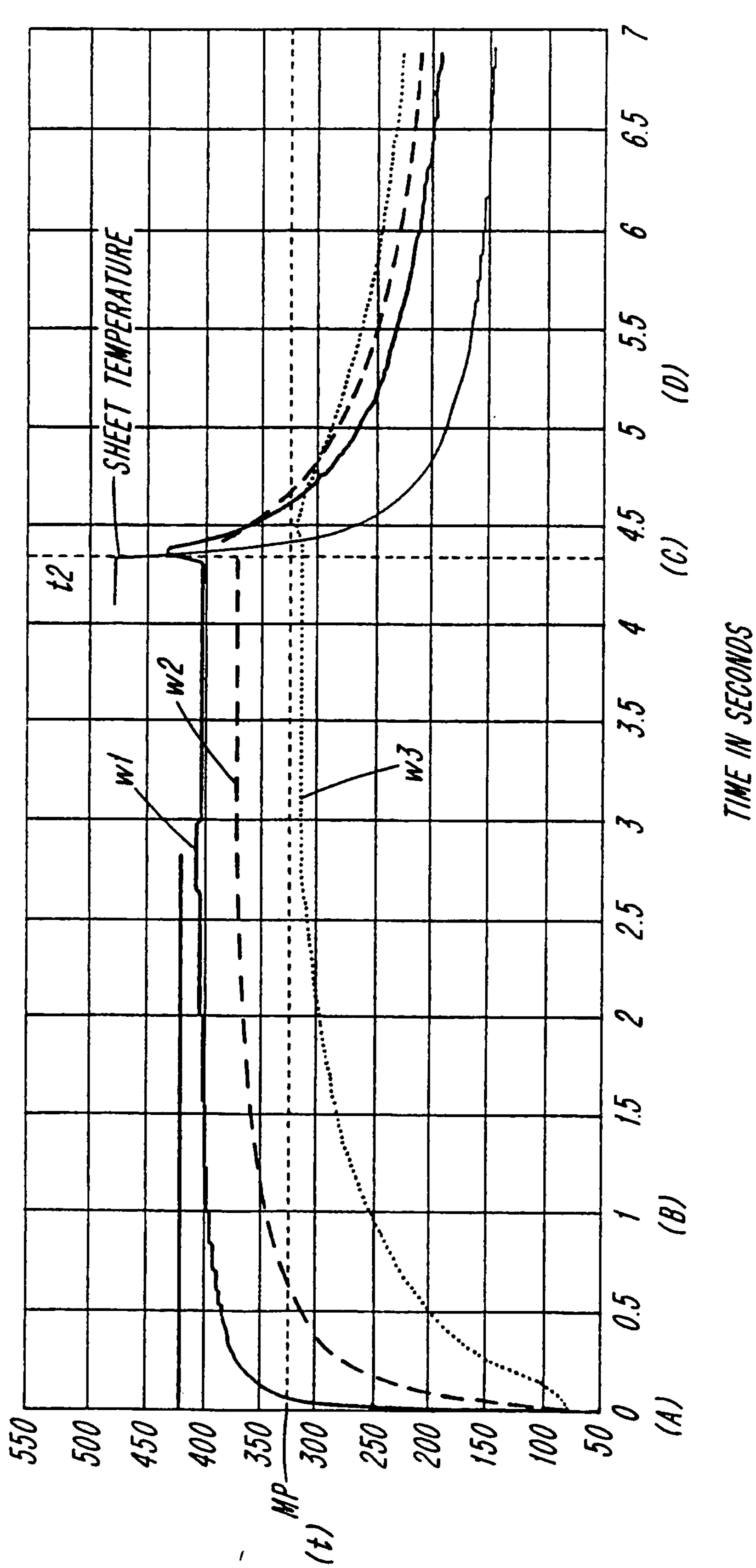
TIME

Fig. 5b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(D)
TIME IN SECONDS

Fig. 6

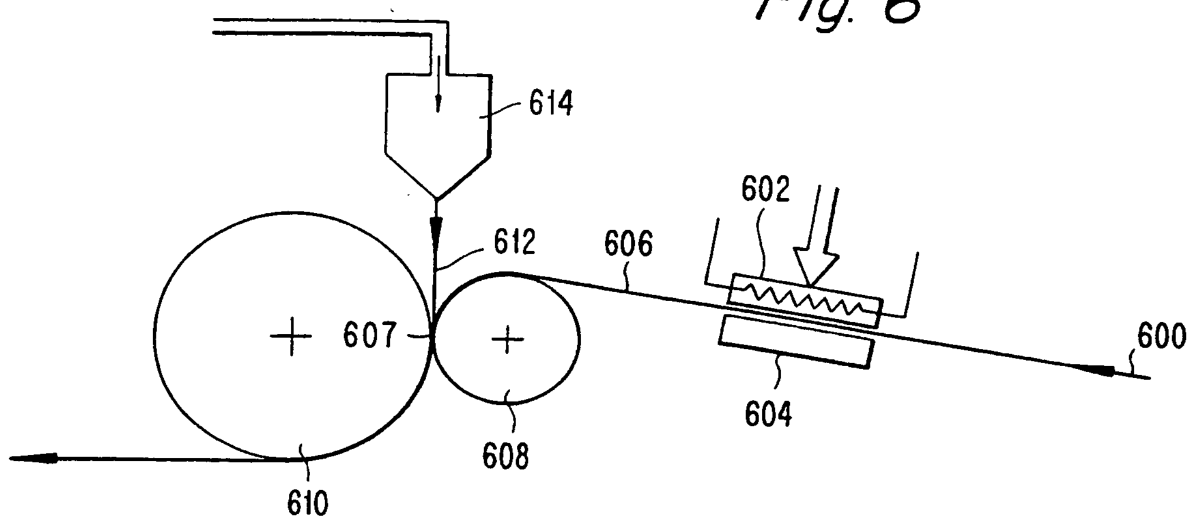
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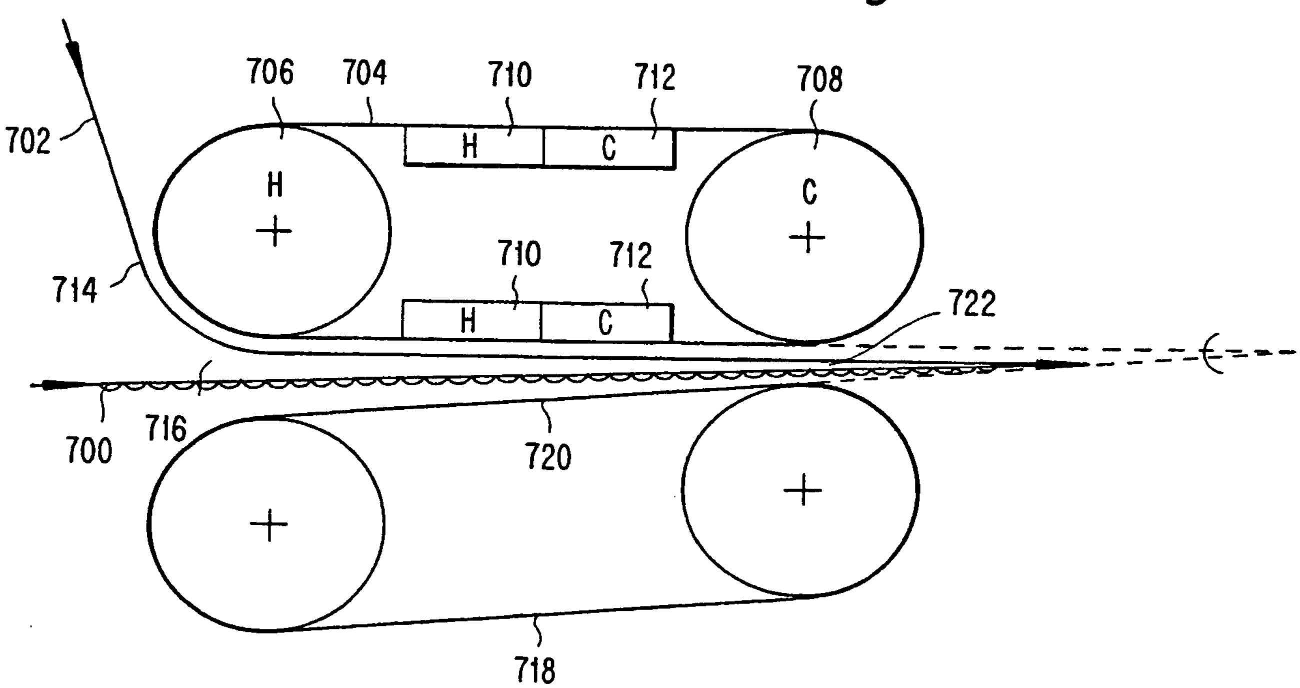
Fig. 7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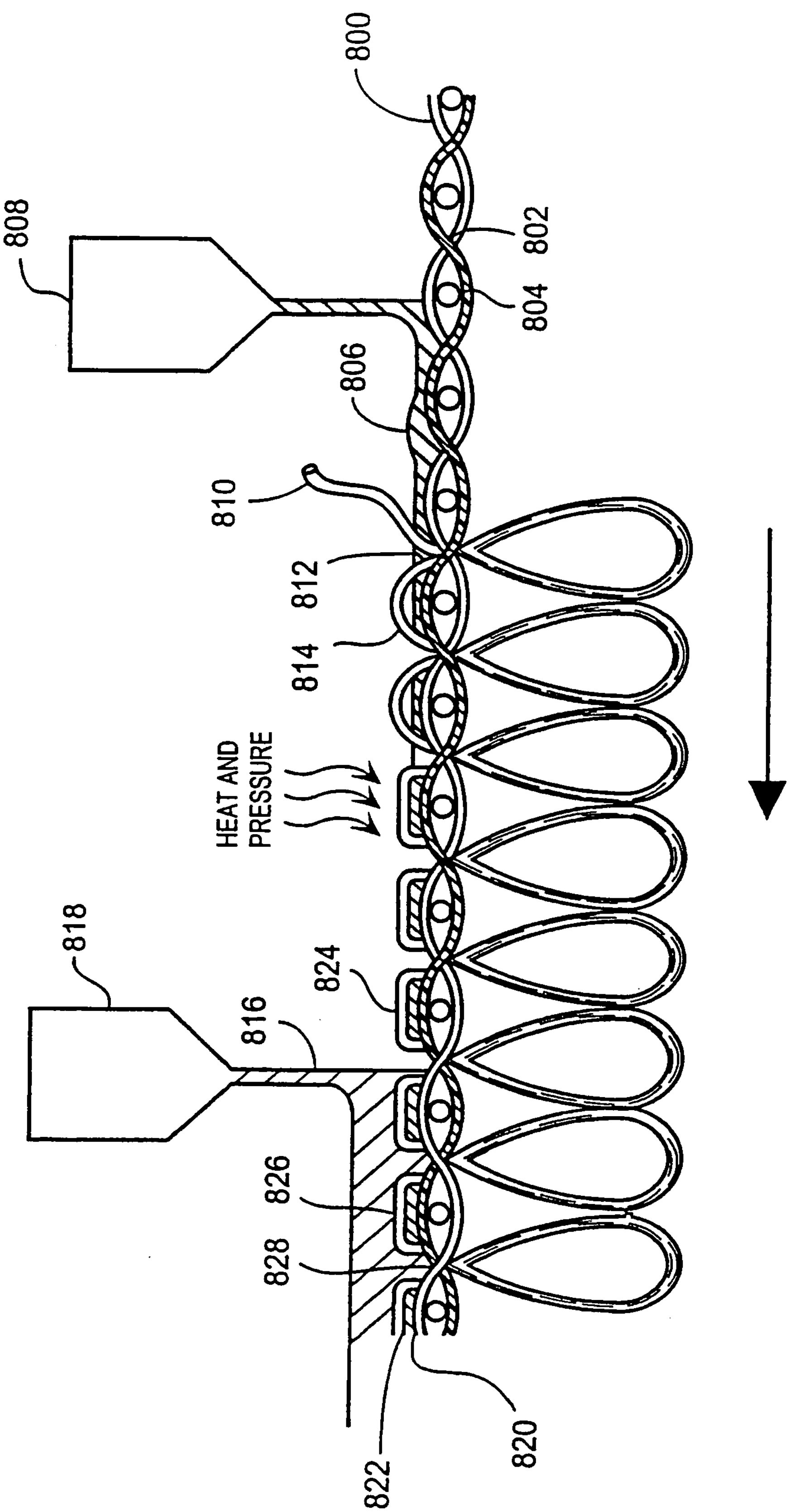
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Fig. 8

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US00/09537

A. CLASSIFICATION OF SUBJECT MATTER

IPC(7) : DO5C 15/04, 17/02; B32B 5/02; B29C 47/02
US CL :428/95, 96, 97; 156/72, 244.11; 427/389.9, 394
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 428/95, 96, 97; 156/72, 244.11; 427/389.9, 394

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

USPATFULL

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 3,679,469 A (MOORE) 25 July 1972, col. 1, line 63-col. 2, line 14.	1, 2, 4-9, 13-19, and 40-49
X	US 3,676,280 A (SANDS) 11 July 1972, abstract, col. 1, lines 51-66.	1, 2, 4-9, 13-19, and 40-49
X	US 3,551,231 A (SMEDBERG) 29 December 1970, col. 3, lines 25-48.	1, 2, 4-9, 13-19, and 40-49
X	GB 971,958 (DOW CHEMICAL CO.) 07 October 1964, page 2, line 88- page 3, line 47.	1, 2, 4-9, 13-19, and 40-49

[X] Further documents are listed in the continuation of Box C. [ ] See patent family annex.

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"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document published on or after the international filing date

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
23 JUNE 2000	11 JUL 2000

Name and mailing address of the ISA/US	Authorized officer
Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231	CHERYL JUSKA
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INTERNATIONAL SEARCH REPORT

International application No.
PCT/US00/09537

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5,472,764 A (KEHR et al.) 05 December 1995, abstract, col. 2, lines 24-57, clo. 9, line 28-col. 10, line 24.	1-19 and 40-49
X	US 5,229,456 A (ILENDA et al.) 20 July 1993, col. 7, line 5-col. 8, line 12, col. 11, lines 20-33, col. 12, lines 3-22.	1-19, 36-49, and 62
X ------- Y	US 3,779,799 A (KENNEDY et al.) 18 December 1973, abstract, col. 2, line 41-57, col. 3, lines 35-col. 4, line 18.	20-26, 28-31, 33-35, 50-55, 57, 59-61 ------ 27, 32, 56, 58